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COVER PICTURE

Management at Colonial Radio Corporation keeps a sensitive finger on quality as Works Manager, Clark Ryan, center, reviews with Chief Inspector, George Herrold, right, and Quality Manager, Alfred Winterhalter, left, the control charts on the first piece parts for post-war radios.

EDITORIAL

QUALITY CONTROL OF POST-WAR INDUSTRY

A segment of unknown size of the industrial plants of the nation employed quality control technique during the period of production for war. The goal of these producers was primarily improvement of quality, and to the editor's knowledge they achieved that goal without exception. The testimonials of government inspection officers and of these concerns' own managements are sufficient evidence on the point.

The operators of plant quality control systems who have carried on the spade work of this splendid accomplishment have been so completely engrossed in the direct quality challenge that they have in most cases neglected the strategy of their positions in the plants' organizational plans. That this would happen was more or less inevitable, because many quality control operators have from the start been put on the defensive by well-intrenched managerial groups loath to permit the intrusion of a new idea that appeared to the uninitiated to offer a threat to established control procedure. Happily this description does not apply to all concerns. Likewise in many plants the initial resistance has disappeared, once the quality control operator has discovered that his is a task of coordination of activities of existing functions, and leaders of these functions have discovered that the quality control operator is a powerful ally and in no sense a threat.

But the position of the quality control operator is insecure for a different reason. His devotion to quality has been so complete that he has not taken the time to show top management in plain dollars-and-cents figures the value of his program to the company. This omission is the expression of a virtue which all quality control operators should possess, namely willingness to let their results speak for them. At the same time lack of awareness by top management has created a situation in some plants during the present reconversion period, which is unhealthy for the future of quality control. Naturally, management must reduce expenses, but a direct reduction made by decimating the quality control department is an invitation to increase in cost of post-war product. Cases have come to attention in which the quality control operator and his staff have been summarily dropped. In other cases personnel cuts have been made "across the board" including the quality control department. In one case the Quality Control Engineer was retained but his staff of ten people was dropped. This is short-sighted policy which perhaps could have been altered, if the management had been kept fully informed of the department's activities and savings.

The opposite of this experience is found in concerns that have made no cuts or only nominal cuts in the quality control staff. Others have expanded their control programs, recognizing that even greater advantage will result from such program in the post-war period than was the case in wartime. This is the sound point of view. During the war the emphasis was on speed and quality of production. The government was in no position to quibble over price. Post-war competition will put the emphasis on quality and price. The plant which plans to reduce cost of production through efficient design, maintenance of quality of purchased material, elimination of out-of-tolerance production, and achievement of truly random assembly will be laying the groundwork of competitive advantage. Savings in these four directions will come with the aid of a quality control program. There is good reason to doubt whether they can be realized in the absence of a quality control system. Post-war manufacturing will be characterized by complex machinery, complicated design, close tolerances, exacting inspection, and high speed operation. There will be no return to pre-war methods, and management must be prepared to institute new controls of the new production techniques. Control through the application of statistical procedures is the available device; it should be installed now as an integral part of reconversion.

Quality control operators who are facing the effects of lack of recognition by management are in a difficult position. Even though the action comes late, they should hasten to report to the proper officials the dollars-and-cents results of their wartime activities. To do so could hardly worsen their positions and could be the means of rescuing them from precarious situations.

Sequential Sampling Inspection for Attributes

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Introduction

Sampling inspection procedures fall into two general categories: (1) procedures for inspection for **attributes**, where the quality of a single unit of product is rated defective or nondefective, and (2) procedures for inspection for **variables**, where the quality of a single unit of product is measured along a scale. This article considers briefly the application of sequential principles to sampling inspection for attributes.

This article is confined to attributes for two reasons. First, attribute inspection is the more common in industry and second, it is easier to introduce the reader to sequential sampling principles by application of these principles to attribute inspection. But sequential sampling procedures for variables have been developed and many statements made in this article hold for variables as well as for attributes.

Three Phases of a Sampling Plan

Any sampling plan may be thought of as having three phases: (1) a **plan of action**, that is, a set of rules and procedures on the basis of which the inspector makes a decision to accept, reject, or defer judgment on each submitted lot of product, (2) the **protection** afforded by the plan of action, that is, the proportion of good lots that will be accepted and of bad lots that will be rejected if that plan of action is regularly used, and (3) the **cost** of the plan, that is, the average amount of inspection required to reach a decision to accept or reject a lot.

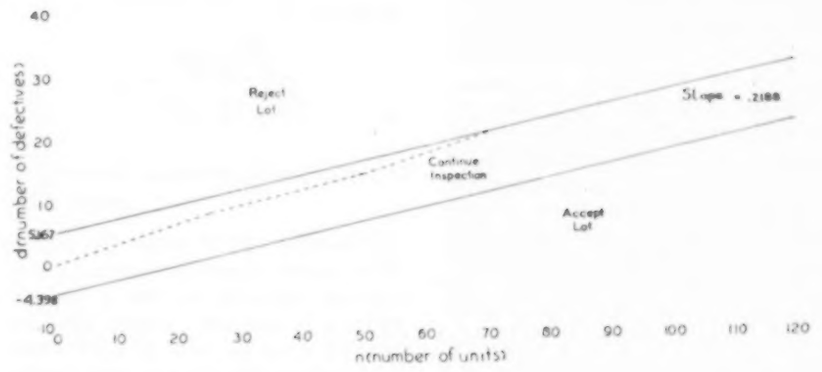
We shall briefly consider these three phases for a sequential sampling inspection procedure.

Sequential Plan of Action

In sequential sampling inspection, the inspector draws at random a sample of n_1 units from a lot. He inspects each unit to determine whether it is defective. If the total number of defective units he finds is equal to or less than the acceptance number e_1, he accepts the lot; if it is equal to or greater than the rejection number f_1, he rejects the lot; if it falls between e_1 and f_1, he neither accepts nor rejects but draws at random a second sample of n_2 units from the lot and inspects them. If the total number of defective units in the two inspected samples is equal to or less than the acceptance number e_2, he accepts the lot; if it is equal to or greater than the rejection number f_2, he rejects the lot; if it falls between e_2 and f_2 he neither accepts nor rejects but draws at random a third sample, etc. This is continued until a decision can be made to accept or reject the submitted lot.

Figure 1

Sequential Plan of Action; Graphical



A typical sequential plan of action, as it appears to the line inspector, is shown in Table 1. The plan of action is contained in the first five columns counting from the left; the actual results of inspection are entered in the column to the right. To illustrate the use of this plan of action, we have assumed that a lot was submitted and that the data in the right hand column were obtained; these data lead to a decision (to reject the lot) after three samples (a total of 75 units) have been inspected.

An alternative method of presenting a sequential plan of action is by use of a graph, as shown in Figure 1. The plans of action of Figure 1 and Table 1 roughly correspond but they differ in two respects which deserve notice. In Figure 1, a lot could be accepted if the first 21 units inspected were nondefectives, and a lot could be rejected if the first 7 units inspected were defectives; in general, it is easy to see that decisions to accept and reject could sometimes be made before 25 units were inspected, between 25 and 50 units, etc. Table 1, on the other hand, requires that inspection be carried out in groups of 25 units at a time, and that decisions to accept or reject be made only at the end of a group. The main reason for this is that groups of substantial and familiar size seem to work out better in routine inspection; the flexibility of the true sequential "unit-by-unit" plan of action of Figure 1 is sometimes too difficult for the line inspector to follow. The inspec-

Table 1

Typical Sequential Plan of Action; Tabular

		Combined Samples			
Sample	Sample Size	Size	Acceptance Number	Rejection Number	Number of Defective Units Found
First	25	25	1	11	8
Second	25	50	6	17	14
Third	25	75	12	22	22
Fourth	25	100	17	28	
Fifth	25	125	22	33	
Sixth	25	150	28	38	
Seventh	25	175	43	44	

tion results assumed in Table 1 are plotted in Figure 1 and they lead, as before, to rejection of the lot after 75 units have been inspected.

The plan of action of Table 1 is truncated at 175 units, that is to say, at this value, the acceptance and rejection numbers differ by unity and hence, it is impossible to inspect more than 175 units from any one lot without reaching a decision. This point of truncation is not indicated on Figure 1 simply because the scale of Figure 1 does not happen to extend that far. The method of selecting the number of units at which to truncate the plan of action is given later.

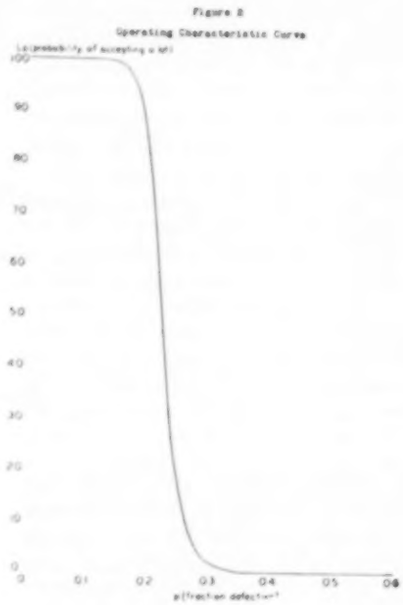
The peculiar feature of the sequential procedure is in its plan of action. Unlike older procedures in which the amount of inspection per lot is fixed or almost fixed before inspection is begun, the sequential procedure does not fix the amount of inspection for any given lot. For example, in the plan shown in Table 1, a submitted lot may sometimes be accepted or rejected after only one sample (25 units) is inspected, sometimes after two samples (50 units) and sometimes only after seven samples (175 units) are inspected.

In sequential sampling inspection, the amount of inspection is primarily determined by the quality of the submitted lot. Conspicuously good lots will usually be quickly accepted, for the smaller acceptance numbers will seldom be exceeded; similiarly, conspicuously bad lots will usually be quickly rejected, for the smaller rejection numbers will seldom be fallen short of; extensive inspection will be required chiefly by lots of intermediate quality, and this is as it should be, because the quality of such lots is more difficult to determine.

Protection Afforded by the Sequential Plan of Action; the Operating Characteristic (OC) Curve

There are clearly many possible sequential plans of action and the problem arises how to choose among them. One important basis of choice is the amount of protection afforded by each plan of action, that is, the relative frequency with which each plan of action will accept good lots and reject bad lots, or, using the term protection in a more general sense, the frequency with which each plan of action will accept lots of any given quality, not only lots that are termed good or bad.

This information is contained in the Operating Characteristic (OC) Curve. The OC curve of a sampling plan shows the relative frequency L_p with which lots containing fraction defective p will be accepted. The relative frequency of rejection of a lot of fraction defective p is simply $1-L_p$. The OC curve of the sequential plan of action of Figure 1 and, roughly, that of Table 1, is shown in Figure 2.



If the sequential plan of action shown in Table 1 and Figure 1 is used we may, for example, be confident that about 98% of all lots containing 16% defective will be accepted, about 78% of all lots containing 20% defective will be accepted, and about 8% of all lots containing 27% defective will be accepted. If the protection indicated by this OC curve is not suitable for the product at hand, the plan of action shown in Table 1 and Figure 1 should not be used. Each plan of action has a unique OC curve and it is generally possible to find a sequential plan of action which has a suitable OC curve.

Cost of the Plan of Action; the Average Sample Number (ASN) Curve

Some plans of action may be said to "change their minds" sharply when a bad lot is substituted for a good one; others discriminate less sharply. The OC curve in Figure 2 shows the degree of discrimination that can be expected if the plan of action of Figure 1 is used. Assume that lots containing 13.6% or fewer defective units are called good while lots containing 25.5% or more defective units are called bad; the plan of action of Table 1 and Figure 1 will accept at least 99.7% of the good lots while it will accept a maximum of 15.1% of the bad lots. There are, of course, sequential plans of action that discriminate more sharply (i. e., have steeper OC curves) and less sharply (i. e., have flatter OC curves).

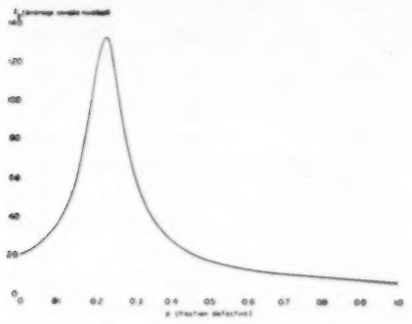
In general, plans of action with steep OC curves would be desired but for one important drawback; they require larger amounts of inspection before a decision on the lot can be reached than do less steep OC curves. So, though a plan of action may have a suitable OC curve, it is generally necessary to determine how much sampling it requires before putting the plan into use.

In sequential sampling inspection the amount of inspection needed on any given lot of given quality cannot be accurately predicted in advance of inspection; this is due, of course, to the unpredictable nature of the sample or samples drawn from the lot. But if a number of such lots are submitted, the **average** amount of inspection per lot is predictable. Thus, if a single lot of quality p = .255 is submitted to an inspector who is using the plan of action shown in Table 1, the amount of inspection required may be anything from 11 units (the minimum number to reject) to 175 units (the maximum number to accept or reject). But if many lots of that quality are submitted, the average amount of inspection per lot required by that plan of action is determinable; it turns out to be about 104 units.

This important information is contained in the Average Sample Number (ASN) curve of a plan of action. This ASN curve shows the average amount of inspection per lot $\bar{n}_p$ if the fraction defective in the lot is p. The ASN curve for the plan of action of Figure 1 is shown in Figure 3.

If the plan of action shown in Figure 1 is used, we may expect that if lots containing 13.5% defective units are submitted, the average amount of inspection per lot will be approximately 50 units, though the actual amount of inspection for any one of these lots is uncertain. If lots containing 30% defective units are submitted, the average amount of inspection per lot will be approximately 60 units.

Figure 3
Average Sample Number Curve



The ASN curve shown in Figure 3 is characteristic of ASN curves of sequential plans of action. It is seen that decisions (generally to accept) are quickly made, on the average, when good lots are submitted and that decisions (generally to reject) are quickly made, on the average, when bad lots are submitted. Lots of intermediate quality require more inspection, on the average.

Some Elements of the Algebra of Sequential Sampling for Attributes Sequential Plan of Action

The sequential plan of action shown in Figure 1 is defined by three constants, the two intercepts $-h_1$ and h_2, and the common slope s. The question arises how to choose values for these three constants. Perhaps the best way to do this, that is, to choose a plan of action, is first to select two points on the OC curve; in other words select two quality levels and the protection that is to be attained at these levels. Thus, the user requires that if lots of fraction defective p_1 are submitted, the plan accepts 100 $(1-\alpha)$% of such lots, while if lots of fraction defective p_2 are submitted $(p_2 > p_1)$ the plan accepts only 100β% of them $(\alpha < .50, \beta < .50)$. He fixes two points on the OC curve and asks for a sequential plan of action that will afford such protection.

A sequential plan of action that will afford such protection can readily be determined. From the two points p_1 and $1-\alpha$, p_2 and β, the constants h_1, h_2 and s of the plan of action are obtained as follows:

$$h_1 = \frac{\log\left(\frac{1-\alpha}{\beta}\right)}{\log \frac{p_2}{p_1}\left(\frac{1-p_1}{1-p_2}\right)} \qquad h_2 = \frac{\log\left(\frac{1-\beta}{\alpha}\right)}{\log \frac{p_2}{p_1}\left(\frac{1-p_1}{1-p_2}\right)}$$

$$s = \frac{\log\left(\frac{1-p_1}{1-p_2}\right)}{\log \frac{p_2}{p_1}\left(\frac{1-p_1}{1-p_2}\right)}$$

Sequential Operating Characteristic (OC) Curve

The OC curve of the plan of action specified by these values of h_1, h_2 and s will go through the two selected points. But lots of quality other than p_1 and p_2 may be submitted and it is important to know how frequently they will be accepted and rejected. In short, it is useful to be able to determine the entire OC curve of the plan of action even though the plan is chosen so as to give required protection at two quality levels.

Let L_p be the probability of accepting a lot of fraction defective p. We have

$$p = \frac{x^s - 1}{x^s - 1} \text{ and } L_p = \frac{x^{h_1 + h_2} - x^{h_1}}{x^{h_1 + h_2} - 1}$$

$$p'' = p' x^{1-s} \text{ and } L_{p''} = \frac{L_{p'}}{x^{h_1}}$$

where x is a dummy variable. Systematic substitution of values of $x > 1$ into these equations readily yields pairs of points on the OC curve of the adopted plan of action; after a number of such pairs of points have been determined, a fairly accurate curve can be drawn through them.

Sequential Average Sample Number (ASN) Curve

The cost of a sequential plan of action is determined as follows: let $\bar{n}_p$ be the average amount of inspection if the lot is fraction defective p. We have

$$\bar{n}_p = \frac{L_p(h_1 + h_2) - h_2}{s - p}$$

The sequential plan of action is usually terminated at approximately the larger of $3\bar{n}_{p_1}$ or $3\bar{n}_{p_2}$ where $\bar{n}_{p_1}$ is the average amount of inspection when $p = p_1$, and $\bar{n}_{p_2}$ is the average amount of inspection when $p = p_2$. Both can easily be read from the ASN curve.

Example and Summary

To illustrate briefly the use of these equations, consider the following example: It is desired to run a risk of only 1 in 100 $(\alpha = .01)$ of rejecting product as good as 15% defective $(p_1 = .15)$ and it is also desired to run a risk of only 2 in 100 $(\beta = .02)$ of accepting product as bad as 30% defective $(p_2 = .30)$. The sequential plan of action, OC curve and ASN curve determined by these four values are shown in Figures 1, 2 and 3. The reader may check his understanding of the use of the equations of this section by verifying the following values of h_1, h_2, and s, and the following six points on the OC and ASN curves.

$h_1 = 4.398$, $h_2 = 5.167$
$s = .2188$

x	p	L_p	$\bar{n}_p$
3.00	.1359	.9966	52.63
1.75	.1737	.9490	86.70
1.25	.2001	.7762	121.02
1.25	.2382	.2909	123.11
1.75	.2705	.0810	85.03
3.00	.3205	.0080	50.06

Only a brief account of the algebra of sequential sampling can be given here; many qualifications which are important in practical applications—such as the effects of grouping (in Table 1, the group size is 25) and truncation (in Table 1, the plan of action is truncated at 175 units) are not discussed here. These matters and others are discussed in publications mentioned at the end of this article. But it can be said here that while sequential sampling inspection, as well as all other scientific sampling inspection procedures, has deep roots in modern statistical theory, experience indicates that the practical administrator of product inspection can master without difficulty those few elements of statistical mathematics that are necessary to successful administration. Finally, no mathematics are involved in the line inspector's work; he simply inspects and records the number of defectives he finds.

Comparison of Single, Double and Sequential Sampling Inspection

Readers of this journal are familiar with single and double sampling inspection procedures for attributes and it may be helpful to compare these briefly with a sequential sampling inspection procedure. First, it is evident that the sequential plan of action is more complicated than the plans of action associated with single or double sampling. In single sampling only one sample is drawn and a decision to accept or reject the submitted lot is made after an inspection of the units in this single sample; there is no possibility of deferring judgment. In double sampling, judgment may be deferred after the first sample is inspected, but in no case are more than two samples inspected. In sequential sampling the inspector may have to draw and inspect from one to many samples (in the plan of action of Table 1, as many as 7 samples may have to be drawn and inspected) before reaching a decision to accept or reject the submitted lot, and he cannot, in advance of inspection, know how many samples he will need. It is clearly more difficult to explain and administer a sequential sampling inspection procedure though this difficulty can easily be overemphasized. Sequential sampling inspection procedures are operating with marked success in over 3,000 plants in the United States and this would hardly be possible if the practical difficulties of the sequential plan of action were great.

It is, however, true, that no matter how slight these practical difficulties are, they exist, and unless there are compensating advantages in favor of sequential sampling, single or double sampling is preferable. Such compensating advantages of sequential sampling generally do exist. Essentially, the main advantage of sequential sampling is that for the same protection sequential sampling costs less than either single or double sampling; or stating this is another way, for the same cost sequential sampling gives greater protection against errors — against rejecting good lots and accepting bad lots— than either single or double sampling.

Table 2
Plans of Action

Type of sampling	Sample	Sample Size	Combined Samples: Size	Combined Samples: Acceptance number	Combined Samples: Rejection number
Single	First	10	10	2	3
Double	First	7	7	1	3
	Second	14	21	2	3
Sequential	First	4	4	0	2
	Second	4	8	0	3
	Third	4	12	1	4
	Fourth	4	16	2	4
	Fifth	4	20	4	5

This fact is illustrated in Table 2 and Figure 5A and 5B. In Table 2 we show three sampling plans of action for attribute inspection; one is single, one is double, and one is sequential. These plans of action have been chosen so that the protection they guarantee is approximately the same, that is to say, all three have approximately the same OC curves (Figure 5A). The cost of this protection is seen to be considerably less for the sequential plan than for either of the other two. (The curves in Figure 5B assume that the entire first sample is inspected.)

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Fig. 5A
Operating Characteristic Curves

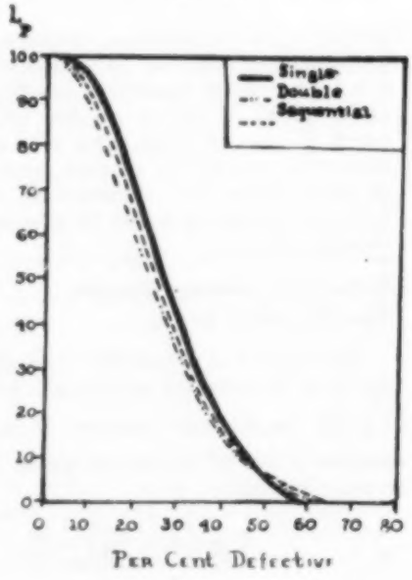
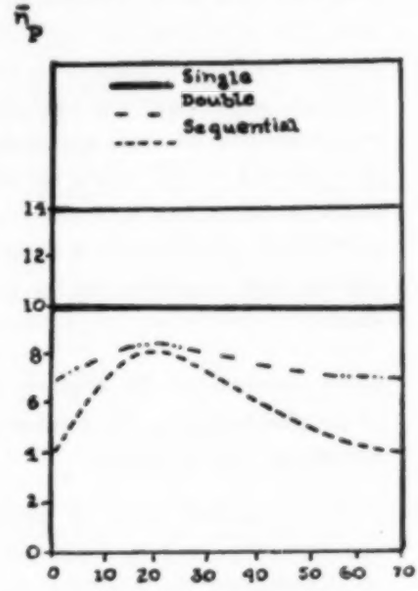


Fig. 5B
Average Sample Number Curves



There is, of course, much more to inspection than protection and the average amount of inspection per lot, and an account of the various merits and demerits of single, double, and sequential inspection would fill many pages. For example, among the demerits of sequential sampling inspection is the fact that quick decisions on submitted lots leave the inspection authorities with but little data from which to calculate such important quantities as the supplier's process

average. But the relative ease with which sequential inspection plans can be constructed, installed, and operated, their flexibility under changing industrial conditions, and their economy in inspection are powerful arguments in their behalf.

References

In this short article only a few aspects of sequential sampling inspection have been discussed. It is hardly necessary to remark that for practical application of sequential sampling principles to attribute inspection, more information is needed. For example, such important questions as classification of defects, formation of lots, and readjustment of the plan of action in the light of accumulated inspection data are untouched by the present article. Moreover, the important field of sequential inspection for variables has not been considered at all.

Information on these subjects is contained in a report titled "Sequential Analysis of Statistical Data: Applications" by the Statistical Research Group, Columbia University; this report will be published about the end of October, 1945 by the Columbia University Press. For the mathematical theory of sequential sampling, the reader is referred to "Sequential Tests of Statistical Hypotheses," by A. Wald, Annals of Mathematical Statistics, June, 1945. Other publications dealing in greater detail with sequential sampling principles as applied to attribute inspection have been issued by the Quartermaster Corps of the Army Service Forces and by the Office of Procurement and Material of the Navy Department, but these publications are not generally available.

Quality Control In The Small Plant

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FREDERICK FLADER Inc.

Quality Control procedure is usually associated with large plants and one frequently encounters the statement "but we are a small plant and do not need advanced methods of control." This statement requires analysis and explanation. Presumably a definition of "small plant" would come first. The author has no intention of attempting to establish a technical definition of "small plant," but would call attention to the fact that of 184,230 manufacturing establishments reported in the 1939 Census of Manufacturers of the U. S. Department of Commerce, 168,814 or 91.6 per cent had one hundred or less wage earners.

The premise that need for control is related to size of operation is untenable. It is perfectly true that some of the devices of management can be dispensed with when personal acquaintance can be substituted for written procedure, but Quality Control does not fall in this category because the improvement of product quality through increased knowledge of processes and operations is quite independent of the personal contact factor. Wherever operations of any sort are being carried on repeatedly for the purpose of obtaining products which are intended to be alike with respect to one or more defined characteristics, quality control of products and processes will yield profitable results.

The type of control installation that will be profitable is determined by the number of pieces in a run or more precisely by the length of a run. In either a large or small plant lots of a few hundred for which the set-up and running time may be not more than two or three hours do not permit the use of control chart technique. On the other hand, continuous production can be controlled by charting in a small plant just as well as in a large plant. The important question then is type of operation.

There are, however, some circumstances connected with the small plant which must be taken into account. In the smallest plants the general manager, the chief engineer, the tool setter, the inspector and the foreman are likely to be one person. As size increases, there is differentiation of function, but the rule of the small plant is overlapping and poor definition of jobs. Offsetting this is the greater skill and initiative to be found in the small plant. Personal contact and verbal instructions are the rule; which means that engineering changes are made by conference and blue-prints are commonly not up-to-date. Often there is no inspection except the checking of dimensions by operators; in that case no inspection records will exist. In fact, the gaging equipment is likely to be meager and indifferently maintained. Both equipment and material in process suffer from poor handling because of lack of space and the absence of methods engineering. There are no training programs in small shops; every man learns his job the hard way. Finally, small plants are likely to be job shops that operate with small orders and short runs.

QUALITY INVENTORY

The first step in installing a Quality Control system is the determination of existing quality. This means the recording of amount and cost of scrap and rework for at least the major products. The rejection of shipments by customers and customers' complaints should also be recorded. In all cases the causes should be broken down as much as possible. Analysis of these records will indicate where customers' complaints can be eliminated, where money savings can be made, what faults are chronic, and the directions in which corrective action can profitably be undertaken.

This inventory presumably will have to be made by someone as a by-product of his regular job. For that reason the plan should not be too elaborate, likewise the control system growing out of the inventory should be relatively simple. While the overall objective is simplicity, the ruling criterion will be the type of operation.

CONTINUOUS PRODUCTION

A small plant may produce a single product or a few products in huge quantities. It may be a machine shop, a spinning mill, a carpet factory, or a pottery. Whatever the field, quantity production lends itself to product control through process control. In brief this means learning what the equipment is capable of doing, if maintained properly and operated properly. The next step is to install whatever type of control will secure the most efficient operation. This may mean the installation of measurement charts in the machine shop, fraction defective charts in the pottery or charts for number of defects in the carpet factory. In all three cases it may be possible to obtain results without using a single chart. The man responsible for the program must possess initiative and be able to make sound judgments concerning the control system that will be compatible with the conditions existing in his plant. But in all cases his activities must be guided by the results of the quality inventory. If $5000 per year is being lost through scrap, rework charges, and rejections, then a control system costing anything less than the part of that sum which the system will save will result in a net gain to the company. Note that there is no place in this analysis for the bromide that quality control cannot be used in the small plant. The criterion is savings vs. costs in terms of the type of operation, not the size of operation.

SHORT RUN PRODUCTON

If a plant is turning out a variety of products in relatively small lots and equipment is being retooled or repatterned at short intervals the problem of control is less simple, whether the plant is large or small. While it is true that some concerns are employing control chart procedure for this type of operation, the author believes that a small plant which attempts this is likely to bog down in the mass of detail involved in maintaining extensive files of intermittently used charts. To avoid this, patrol inspection should be employed. For jobs that have a past record of good quality, first piece-last piece inspection may be adequate. In other cases patrol inspection hourly or at shorter intervals may be required depending on the quality history of the product and the complexity of the operation. In all cases the findings of final inspection should be recorded by types of rejects and the results brought quickly to the attention of operators and management. Pressure from management is usually sufficient to bring corrective action. However, emphasis should be placed on correction of chronic items and costly items. Less troublesome faults can then receive attention. A successful control program will eventually produce a quality level beyond which it will not be economic to press for further corrective action. This is a quality millennium seldom reached in practice, but its achievement would not be the signal for discontinuation of the control program. Rather the program should be continued in a form that will provide adequate insurance against future loss of the high quality level achieved.

WORKERS' ATTITUDE

The Quality Engineer in the small plant has an opportunity to develop personal acquaintance with workers and enjoy their confidence. He is able to get cooperation with his control program. At the same time he must remember that he is usually working with men possessing considerable skill and initiative. An example of doubtful technique has recently come to the author's attention. A sleeve with an external thread was being produced in quantity. No records of inspection were kept, but each day the rejects were dumped into a large box marked "scrap." As the accumulation in the box grew, workers became more cautious, rejections practically disappeared. The doubtful part of the example is the fact that the "scrap" box was salvaged at the end of the job. Such indirection may destroy the workers' confidence in the Quality Engineer.

Operator and inspector can often do quality control jointly without the aid of records. On a grinding operation the inspector called back the size as he measured parts coming from the machine. The operator soon recognized that regular growth in the dimension called for setting the grinding wheel closer, and that rapid growth of the dimension indicated that the wheel should be redressed. This is actually oral control of tool-wear.

CONCLUSION

In the foregoing the writer has tried to stimulate the thought that quality is a cost and production tool and not a field sufficient unto itself. It is very easy to drift into the latter attitude in the large plant operation and the small plant Quality man must early recognize this fact if he is to prove his value. With these adjustments to existing conditions, there is just as much (perhaps more) opportunity for the Quality Engineer in the small plant as in the large one.

Quality Control Reports

Issues numbers 3 and 4 of "Quality Control Reports," published by Carnegie Institute of Technology in conjunction with the O. P. R. D., appeared in August 1945. Number 3 contains an article by Lester A. Kauffman, "Statistical Quality Control at the St. Louis Division of American Stove Company." Number 4 contains an article by Carl G. Schmid, "Quality Control at the Lukas-Harold Corporation." Copies of this report are available without charge to persons concerned with quality control in war industries, educational institutions or government service. Requests for copies should be addressed to Quality Control Program, Carnegie Institute of Technology, Pittsburgh 13, Pennsylvania.

OMISSION

Through an error we failed to report in the July issue that J. M. Juran's "Management of Inspection and Quality Control" is published by Harper and Brothers, New York, at a price of $3.00.

* * *

Four Valuable Articles

William B. Rice, Plomb Tool Company, Los Angeles, has published five articles which contain illustrations of quality improvement and savings resulting from the use of statistical control procedure. They fully warrant the attention of quality control operators. The titles and publishers are: "Quality Control Through Statistics," Western Industry, December 1943 and January 1944; "Setting Tolerances Scientifically," Mechanical Engineering, December 1944; "Scientific Tolerances by Inspection," Mechanical Engineering, March 1945; "Quality Control Applied to Business Administration," Journal of the American Statistical Association, "Statistical Uses of Accounting Data," the Accounting Review, July 1944.

Operating Characteristics Of Reject Limits For Measurements

NORBERT L. ENRICK

HEADQUARTERS, QUARTERMASTER CORPS., INSPECTION SERVICE

The January and March 1945 issues of INDUSTRIAL QUALITY CONTROL contained two articles by A. J. Winterhalter titled "Development of Reject Limits for Measurements." To compute upper and lower reject limits for sample averages, a factor b was developed from the formulas:

URL = Upper Spec. Limit − bR'

LRL = Lower Spec. Limit + bR'

The factor b was tabulated for sample sizes up to 15 and various values of the acceptable defectives. It was so calculated that the average of a sample from a lot containing exactly the acceptable defectives would fall on or outside the reject limits only about three times out of 1000. In other words, the risk of rejecting good lots was fixed at .3%.

Similar reject limits have been found very valuable by the writer in his experience with the Quartermaster Corps. They are best used in acceptance inspection of product required to meet certain quality characteristics, such as the breaking strength of materials, the Rockwell hardness of steel blades, etc., where testing is costly, time-consuming, or destructive, and consequently only a small sample of a few pieces can be tested.

The value of this type of reject limit is greatly increased if operating characteristics curves are available. The curves in Figure 1 are obtained if reject limits are computed from the formulas above, but L factors (Table I) are substituted for the b factors. The L factors were used after a study of operating characteristics revealed that b factors do not provide sharp discrimination between good and bad lots. While b factors are very well suited for the producer's control during production, the L factors are preferable for acceptance sampling.

When reading the curves, the "Percent Defective of Submitted Product" scale at the bottom of the graph must be selected to correspond to the particular value of the acceptance defectives (in %) adopted. The information obtained is twofold:

First, a rough estimate may be obtained of the expected percentage of rejections that will result from adoption of a particular value of the acceptable defectives. The L values are set so that, if all lots offered were per cent defective equal to the allowable per cent nonconforming, 97 per cent to 98 per cent would be accepted regardless of the size of the sample inspected. This is shown on the graph by the convergence of the O. C. curves. Suppose that the allowable per cent nonconforming is 1 per cent, then the use of the reject limits proposed here will produce the following results:

Probability of Acceptance of Lots Which Are

Sample Size	2% Defective	5% Defective
2	.94	.85
3	.93	.78
5	.91	.68
8	.88	.53
10	.85	.43
15	.78	.26

These values have been read from the graph to illustrate the use of the O. C. curves. A more extensive table could be made by adding more values of per cent defective. A similar table could be made for any of the listed values of allowable per cent nonconforming. Second, a rough estimate may be made of the sample size required to meet a desired combination of consumer-producer risks. Suppose that the allowable per cent nonconforming were taken as .5 per cent and that the purchaser wished to protect the vendor from rejection of more than 10 per cent of 1 per cent lots, and wished to protect himself against the acceptance of more than 10 per cent of 10 per cent lots. Inspection of the graph shows that samples of 5 will approximately meet this requirement. Note that the choice of the four values was not entirely free. If the consumer's lot tolerance were set at 5 per cent, the other three values being unchanged, there is no sample size which will meet the requirements. Thus it is seen that the greatest value of the graph lies in determining the consumer's and producer's risks in terms of the sample size, the allowable per cent nonconforming having been set in advance in terms of the requirement of the material in the plant.

Table I: L Factors

Sample Size	ACCEPTABLE DEFECTIVES (in %) .1	.5	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0
2	1.49	1.03	.81	.57	.41	.30	.20	.13	−.01	−.12
3	1.14	.84	.69	.53	.43	.35	.29	.24	.15	.08
4	1.02	.77	.64	.51	.43	.36	.31	.27	.20	.14
5	.94	.72	.62	.50	.42	.37	.32	.28	.22	.17
6	.90	.69	.60	.49	.42	.37	.33	.23	.23	.18
8	.84	.66	.57	.47	.41	.37	.33	.30	.25	.20
10	.80	.63	.55	.46	.41	.36	.33	.30	.25	.21
12	.77	.61	.54	.45	.40	.36	.33	.30	.25	.22
15	.74	.59	.52	.44	.39	.36	.33	.30	.26	.22

DERIVATION OF L FACTORS AND O. C. CURVES

The reader familiar with elementary statistical theory will be interested in the following derivation of the L factors and O. C. curves.

If we are dealing with a normal distribution of quality about an average production level, $\bar{\bar{X}}$, then the percent of product falling outside the upper specification limit, S, may be determined from tables of areas under the normal curve from the relationship:

$$(1)\quad \frac{X}{\sigma_1} = \frac{S - \bar{\bar{X}}}{\sigma}$$

(As explained by M. A. Brumbaugh in the May issue of Industrial Quality Control.)

We note that (1) may also be written, since $\sigma_1 = 1$,

$$(2)\quad \bar{\bar{X}} = S - X\sigma$$

By fixing X to correspond to the acceptable defectives, we can, from the above formula, calculate "reject limits" for the average production level. However, these limits could not be used in lot-by-lot inspection, since only the sample average is known. Consequently, an allowance must be made on the "reject limit" for **process** averages to allow for chance variations in the individual **sample** averages. If an allowance of 2 standard errors $(\sigma_{\bar{x}})$ is made, (2) becomes

$$(3)\quad URL = S - x'\sigma + 2\sigma_{\bar{x}}$$

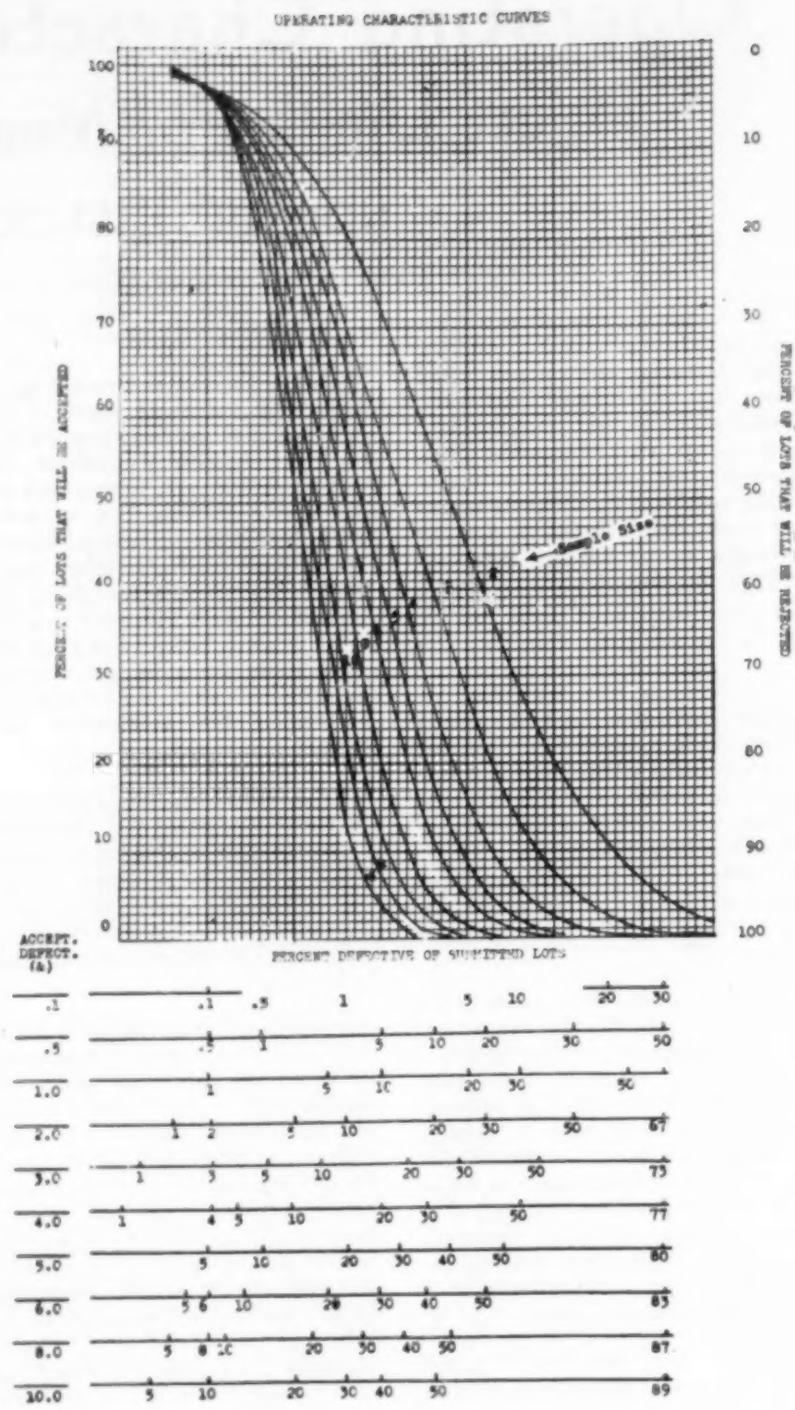
(The ' on X indicates that X is the number of standard deviations corresponding exactly to a particular acceptable percent defective).

Now, (3) may also be written

$$(4)\quad URL = S - \left(x' - \frac{2}{\sqrt{n}}\right)\frac{1}{d_2}R'$$

where the coefficient of R' is L. The reader may easily verify that L could have been obtained similarly with reference to a lower specification limit. Table I has been prepared by substitution of values in the formula,

Fig. 1



$$L = \left(x' - \frac{2}{\sqrt{n}}\right)\frac{1}{d_2}$$

The table of areas of the normal curve shows that an ordinate 3.09 standard deviations above the average will exclude .1 per cent of the area of the curve. Thus for the first value in Table I, $x' = 3.09$ and for $n = 2$, $d_2 = 1.128$, then

$$L = \left(3.09 - \frac{2}{\sqrt{2}}\right)\frac{1}{1.128} = \frac{1.676}{1.128} = 1.49$$

Operating characteristics may be determined from the relation

$$(5)\quad \frac{X}{\sigma_1} = \frac{URL - \bar{\bar{X}}}{\sigma_{\bar{x}}}$$

where the risks of acceptance and rejection may again be determined from tables of areas under the nor-

(Continued on Page 15)

A Report On Pre-War Quality

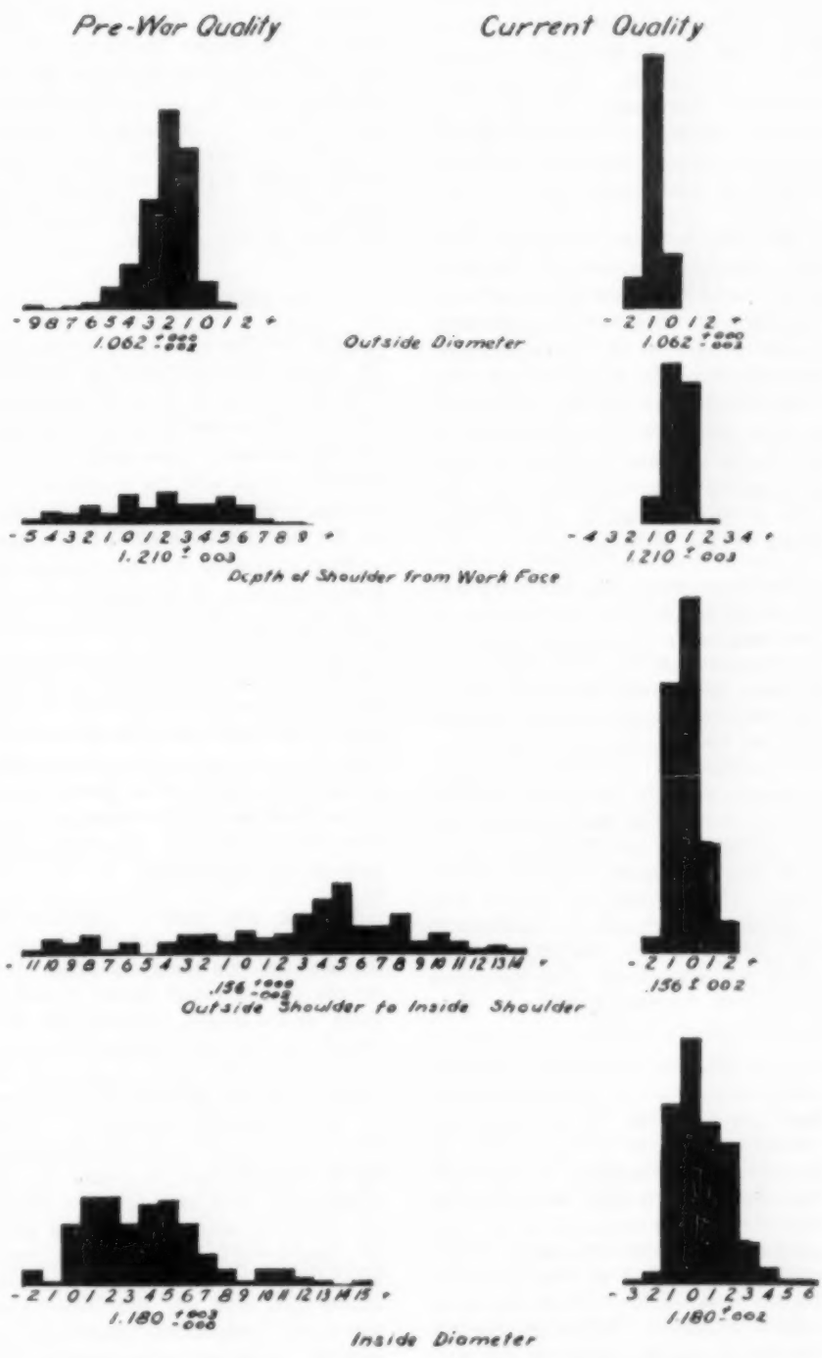
MARTIN A. BRUMBAUGH

BACKGROUND

Conversations with inspection and production supervisors show a general belief that quality suffered in the rush for quantity during the war. These men say that their quality problems were minor in the pre-war period, whereas they multiplied tremendously during the war. In fact, intensification of the quality problem was the major factor in the widespread introduction of quality control technique during the war. There is, however, an additional factor involved in the comparison of the two periods because the requirements of mechanized war forced upon industry closer tolerances and increased inspection. Accordingly, in many respects the war and post-war situation is not comparable to that existing in the pre-war period.

Some concrete evidence on the question of pre-war quality has recently been made available to the author. Early in the war period a large manufacturer converted to 100% war products. A sizable inventory of completed and partly completed parts was in process at the time of conversion. This inventory was removed to a storage warehouse. When this manufacturer's war contracts were cancelled, the management decided to reenter the civilian market quickly by completing the machine operations on the stored inventory articles so that they could be assembled and marketed while the general reconversion of the plant was in progress.

Obviously the source of the information can not be disclosed, but a general description of the product will suffice for the purpose of this paper. The article is a complex assembly consisting of more than 100 piece parts. Tolerances are moderately close and matching piece parts require that tolerances be held. The article was produced in quantity before the war and war production was of a character permitting use of the same machines, although tools, jigs, dies, etc, were different.



RECORD OF THE INVENTORY

The chief inspector was instructed to ascertain the quality of the stored inventory. He found the material to be free of surface deterioration, rust and generally in good condition. Difficulty arose in locating the applicable blue-prints to check dimensions, but finally inspectors were provided with prints and gages and instructed to check a large sample of each dimension. It should be noted that this material had not been inspected at the time of storage due to the quick conversion to war work. The inspectors compiled hundreds of separate sample records in checking the piece parts assembled in different models of the product.

The results were startling. Not more than 14 per cent of the piece parts could be assembled without rework according to the applicable prints. There is, of course, an estimate in this, but the estimate was made conservatively by assuming to be acceptable any dimension in which the sample indicated a high probability that at least 90 per cent of the pieces in a lot were made to the blue-prints.

The accompanying diagram shows at the left the distribution of measurements of the sampled inventory and at the right the distribution of measurements of a random sample of current production for four dimensions that were comparable in pre-war and war products. These four are neither the worst nor the best pre-war distributions. They were chosen to afford contrast with current conditions. The dimensions on the diagram have been altered sufficiently to preclude any chance that they could be recognized. The tolerance limits are quoted exactly as they appear on the prints.

The outside diameter sample showed only a few pieces oversize, but one-third of them undersize which will not function and therefore must be scrapped. By contrast, this dimension is now being held so that little or no scrap or rework occurs and random assembly is certain. The depth of the shoulder from the work face shows an even worse situation. Although the tolerance is greater, only 58 per cent of the pieces in the sample will assemble without rework and 32 per cent are not usable. This is quite a contrast to the present status of this dimension with only half of the range of the print tolerance being used. The distance between the outside and inside shoulder shows the poorest results of the four dimensions. Only 11 per cent of the sample is to blue-print; 20 per cent must be scrapped; 69 per cent must be reworked. The tolerance is now bilateral, but the principal change in current production is the absence of any out-of-tolerance pieces in the sample. The inside diameter results were also poor with 47 per cent of the pieces to blue-print, 3 per cent undersize that can be reworked, and 50 per cent oversize that must be scrapped. Under present conditions this bore is not being made without scrap, but the oversize pieces amount to only 8 per cent of the sample.

CONCLUSIONS

This inventory of piece parts can be made into marketable product only by setting up a small machine shop in the assembly area and then relying entirely upon selective assembly. This will be a costly procedure which is warranted solely on the basis of market advantage.

This company is accustomed to precision work, and was known before the war for the high quality of its products. Yet the measurements compiled from this inventory show the scrap loss which it suffered and the amount of rework that was necessary to assemble out-of-dimension piece parts. There is reasonable doubt whether random assembly was ever achieved in pre-war operations.

During the war a system of quality control was installed throughout the machine shop. The results are obvious in the distributions at the right. Tolerances that could not be held before the war are now held with ease and in some cases design has closed tolerances to simplfy assembly. With the aid of control charts operators have learned how to avoid loss of dimension; tool setters have learned how to reduce shutdown time of equipment. During the war, production of good parts per machine-hour and per man-hour was more than doubled. Random assembly replaced the fit and file assembly procedure of the pre-war period. No difficulty was encountered in meeting government inspection requirements.

In the post-war period this company is prepared to machine parts to blue-print, and assemble at random with nominal rework and repair. The result will be a better functioning product. At the same time lower costs will give a market advantage over competitors.

The Quality Control Engineer of this company would not be willing to take credit for this obvious improvement in product quality. To him it has been a cooperative piece of work participated in by production supervision and operators, by inspection, by methods engineering, and by design. At the same time management has supported the quality control program and is prepared to strengthen and expand it in the post-war period.

To the author this example shows that (1) perhaps pre-war product quality was not as good as has at times been claimed, (2) quantity is not inconsistent with quality when a control system is in operation, (3) a concern that has learned quality control during the war carries a competitive advantage into the post-war period.

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SOCIETY REPORTS

Boston Group

Forty-five people who attended a recent eight day course on quality control at Northwestern University held a follow-up meeting August 18. Professor Harold A. Freeman of Massachusetts Institute of Technology gave an excellent, well received discussion of sequential sampling. The afternoon session was devoted to discussions by F. G. Smith, American Brass Company, Leonard H. Sedar, General Electric Company, Warren P. Purcell, Sylvania Electric Products Company, and Douglas Benedict, General Electric Company.

A committee composed of Douglas Benedict, Elmer E. Haskins, Charles J. Hudson, Warren R. Purcell, and Leonard A. Sedar was named to plan for the October 6 meeting and submit an organizing plan for a Quality Control Society.

Newark Society for Statistical Quality Control

The first meeting of the year will be held October 22 at the Newark Academy. The topic is to be "Applications of Statistical Quality Control in Chemical Engineering." The program committee anticipates having Paul Peach as a speaker.

Society of Quality Control Engineers of California

Forty-seven members and friends of the Quality Control Engineers of California met July 10 at the Los Angeles Athletic Club for a dinner meeting. J. M. Howell reported the progress on the formation of the Organizing Committee for the proposed National Quality Control Society. Clifford Bell of the University of California was announced as an additional member to the Advisory Committee. Dr. Bell stated that the University of California is cooperating in continuing quality control training courses under its University Extension Service. Preston C. Hammer reviewed J. M. Juran's recent book "Management of Inspection and Quality Control."

A round table discussion "Adapting Theory to Practical Problems" was led by J. M. Howell. The use of p charts for sheet metal fabrication data was the major item presented. Dr. Hammer stated that the conventional p chart is not satisfactory for this type of data, since the requirement of randomness is not fulfilled. He proposed the per cent defective data be adapted to an $\overline{X}$, R chart. This chart employs a moving average over two successive weeks and the range is obtained by taking the difference of the two successive values. Two sigma limits seem to be most practical for this chart.

W. B. Rice, Director of Statistics and Reports for the Plomb Tool Company of Los Angeles, made available to the members of the Society reprints of recent articles he published in national journals. At the next meeting, October 18, nomination and election of officers for the ensuing year will be conducted.

Northwestern University Quality Control Group

The fourth follow-up meeting was held August 9. D. Pickering of the Parker Pen Company reported how the use of $\overline{X}$ and R charts and fraction defective studies reduced a defect level from 7.5% to 2.5% and ultimately to 0.6%. J. J. McVady, Inspection Foreman for International Harvester Company, told of his "fact finding tour" as the first step in applying statistical methods of quality control to ball bearing manufacture. The use of charts prepared by the inspection department secured the cooperation of the engineering department in condemning one machine which had been ignored previously as a source of bad production.

Alden's Chicago Mail Order Company buys 4625 items from 1317 suppliers, and management spends large sums on inspection to assure adequate protection to its customers. How the company set up a long term program by which supplier ratings will be established was presented by C. T. Herzfeld.

E. L. Fay, Chief Inspector of the John Deere Tractor Works, told the story of the introduction of statistical methods in his plant. His talk included the use of slides and the benefits derived from their new methods resulted in the reduction of reclaim work, which kept three men busy full time, to a point where one man spends two hours a day on the same work.

Mr. Schroeder and Professor Rogers used charts adapted from the data presented previously by Mr. Gretzlaff to illustrate how a process for lens grinding was brought under control.

Pittsburgh Quality Control Society

The Pittsburgh Quality Control Society has arranged a series of programs for the coming year, the first of which was held at Carnegie Institute of Technology in Pittsburgh on September 20. E. G. Olds, Associate Director of the Quality Control Program, was the principal speaker. His subject, "Sequential Sampling in Quality Control Work."

At least four technical sessions will be held for the 1945-6 program as follows: November 15, January 17, March 21, and May 16. In addition, open forum meetings for the discussion of members' problems are scheduled for October 18, February 21, April 18, and June 20. Interest among members remains high and the enrollment of a number of new ones adds to an already encouraging outlook.

Illinois Quality Control Group

The fifth continuation meeting was held at the University of Illinois, June 29 and 30. An excellent program was presented by L. W. Bayles on "Calculation of Control Limits for the $\overline{X}$, R Chart in Relation to A. Q. L.," by R. W. S. Freeman on "Three Quality Control Problems in Foundries," by C. M. Noble on "Gages and Gaging Practice," and by W. T. Hayter on "Control Problems in Electrolytic Training." Mr. Bayles explained the use of modified control limits where a manufacturer has accepted a contract to supply a product whose linear measurements are fixed by a specification and cannot be altered and where the specification states the A. Q. L. of the product.

Mr. Freeman's talk related to the use of statistical quality control in a cast manganese steel plant, a brass foundry, and in jobbing

shops. The talk clearly illustrated the general plan of attack for an investigation and concluded that "the man on the job must accept a major share of the responsibility for the detection and correction of assignable causes" is a bit unwarranted, at least in the foundry field.

Mr. Hayter prefaced his comments with a short history of the use of tin plate commercially and the problems involved in starting the electrolytic tinning industry when the capture of the major tin supply sources by the Japanese made a reduction of the use of tin in this country imperative. His talk described the electrolytic tinning processes and the problems involved in controlling them. Mr. Hayter believes that at least 50% of the value of charts is psychological, providing they are in full view of the men doing the work.

Delaware Quality Control Society

After meeting regularly for five months, our group organized formally at a meeting held on June 19.

Officers for the year are Charles A. Bicking, Chairman; Victor M. Gelin, Vice-Chairman; Howard S. Clark, Program Chairman; William H. Markwood, Jr., Membership Chairman; and, Benjamin O. Nelson, Secretary-Treasurer (9150 Du-Pont Building, Wilmington, Delaware.)

Our members are interested particularly in applications of Statistical Quality Control to problems in Chemical production and research. We feel that much of the work we are doing is pioneering. There is little published literature in this field.

Perhaps others are working on the same type of problems. If so, we welcome your inquiries and your help.

Toronto Quality Control Society

The following is a brief report on the talk given by Dr. E. C. Olds at the meeting September 12, 1945.

Under the title "What Management Should Know About Quality Control in Industry" Dr. Olds of the W. P. B. Washington outlined the history of quality control as such in the United States. Following this the speaker made reference to two practical applications of Quality Control. The applications served a dual purpose in that they also revealed at least the elementary stages of the mathematics and statistics forming the foundation of Statistical Quality Control.

Dr. Olds made reference to the quality/price ratio which is seriously effected by quality changes. Statistical Quality Control as a production and inspection tool is a possible means of improving this important ratio, either by improving quality, reducing price or by both.

Special mention was made of the inspection programs now being put into effect. These methods while doing away with 100% inspection will guarantee the outgoing level of quality at **any** chosen value.

Future meetings of the Toronto Quality Control Society. All meetings are the second Wednesday of the month at 8.00 p. m. at Ontario Research Foundation.

October—J. McKeigan Esq. Application of Q. C. to Small Arms Production.

November—J. C. Langford, Asst. Q. C. Superintendent, Cherrier Works, D. I. L.

December—Dr. M. A. Brumbaugh of the University of Buffalo.

Quality Control Engineers of Rochester

The first meeting of the fall season was held at the Chamber of Commerce on September 11. Any concern over the possibility of declining interest in our group was quickly allayed when 183 men and women appeared for this meeting.

The meeting was arranged as a joint undertaking of our general membership and the sub-group on Gage Control.

The speaker of the evening was Mr. Clinton V. Johnson, member of the firm as well as Chief Engineer and Sales Manager of the Johnson Gage Company, Bloomfield, Connecticut.

Mr. Johnson is a former member of the American Gage Design Committee. In addition, he has held the positions of Sales Engineer for the John-Sons Gage Works and Chief Sales Engineer for Pratt & Whitney Division, Niles - Bemond - Pond. It was with this excellent background that Mr. Johnson presented in a most interesting and informative manner the subject of "Quality Control Problems in Screw Threads."

As was reported in the last issue, Dr. Brumbaugh recently conducted a series of five lectures on Sampling at the Rochester Institute of Technology. As a result of this undertaking an additional subgroup of our membership is being formed to continue work and discussion in this area of Quality Control. The first meeting of this subgroup will be held at the Chamber of Commerce on October 24.

PLANT ACTIVITIES

Sylvania Electric Products Company, Williamsport, Pennsylvania

Sylvania's Williamsport Plant reports that progress in the use of quality control techniques is continuing at a rapid pace. Twenty-four active control charts are maintained on the factory floor with several others being planned. The quality control group also makes special studies on parts and assembly quality and studies the comparative effectiveness of various kinds of chemical processing.

Fulton Syphon Company

Recently a four page booklet written for the layman by F. H. Thomas was distributed to all employees of the Fulton Syphon Company. This booklet explains what quality is; what part the worker has in quality as it affects himself and his company.

Sylvania Electric Products Company, Emporium, Pennsylvania

The Emporium Plant of Sylvania reports that prior to using a modified limit plan based on the specifications instead of the process average, three quarter of a million measurements a month were made. With the advent of this plan, the amount of work was reduced approximately 70% and a better product is being shipped. Data were compiled which aided the Engineering Department tremendously. Statistical analysis is being used in making recommendations for revisions in the specifications and for the assignment of work to machines.

(Continued from Page 10)

mal curve. However, (5) is not suitable in its present form, since it would require an infinite number of O. C. curves to be drawn in order to represent all possible sigmas that may be encountered. (5) is therefore converted by substitution from (2) and (3) to

$$(6)\quad \frac{\chi}{\sigma_1} = \frac{(S - x'\sigma + 2\sigma_{\bar{x}}) - (S - x\sigma)}{\sigma_{\bar{x}}}$$

which reduces to

$$(7)\quad \frac{\chi}{\sigma_1} = (x - x')\sqrt{n} + 2$$

which can readily be evaluated for all possible combinations of the acceptable percent of defectives (corresponding to X'), the incoming percent defectives (corresponding to X), and sample size, n. It should be noted that in plotting the O. C. Curves a method of graphic approximation was used which may result in slight (unimportant) differences of the plotted values from the exact, calculated risks.

If, instead of the L factors, b factors had been used, (7) would have become

$$(8)\quad \frac{\chi}{\sigma_1} = (x - x')\sqrt{n} + 3$$

University of Toronto Lectures

The series of lectures on quality control presented recently at the University of Toronto by Dr. A. E. R. Westman of the Ontario Research Foundation will be published serially in "Manufacturing and Industrial Engineering," Consolidated Press, 73 Richmond Street, West, Toronto 1, Ontario. The series will begin in either the October or November issue.

BUFFALO MEETING

The first fall meeting of the Society of Quality Control Engineers was held September 24 at the University of Buffalo. After a few brief notices and a financial report by Kenneth Conrad, newly appointed treasurer, the meeting was turned over to Mr. W. T. Dunlap of the Research and Development Division of the Electro-Metallurgical Co., Niagara Falls, N. Y.

Mr. Dunlap gave the first talk we have heard on the application of

(Continued on page 16)

ARTICLES OF FEDERATION

BETWEEN THE SEVERAL QUALITY CONTROL ENGINEER SOCIETIES

At two meetings held September 8, 1945 and October 6, 1945 accredited representatives of four quality control societies—Michigan, Rochester, Syracuse, and Buffalo developed the following plan for mutual action.

BELIEVING, in Quality Control as a science whose application to industrial situations will provide the means whereby standards of quality, workmanship, and efficiency in fabrication can be materially increased over those now in effect, to the definite improvement of industry as a whole and for the benefit of individuals employed therein. And,

BELIEVING, that the universal acceptance of Quality Control by industry can be achieved only by intensive effort on the part of active operators in the field, and that the present is most propitious for such undertaking. And,

BELIEVING, that there exists a distinct need for mutual assistance among the operators. And,

BELIEVING, that no one group can accomplish this, we the several societies subscribing hereto, do band ourselves together in a federation of mutual co-operative effort for the benefit of the Societies as unities, for the individual memberships thereof, and for the science of Quality Control. We do hereby subscribe to the enumerated purposes as set forth herewith and to a program dedicated to the advancement of Quality Control, to the further education of our respective memberships, and to the acceptance of our program by industry.

THE OBJECTIVES OF THE FEDERATION SHALL BE:

I The retention by the member societies of their autonomous powers and identities.

II The pooling of their resources in the field of common interest and problems.

III The joint publication of the magazine INDUSTRIAL QUALITY CONTROL through the combined business management and editorial board established by the member societies. The objectives for the magazine are wider scope, enlargement of content, and an editorial policy committed to presentation of problems of quality control operators, principles of quality control, and demonstrations to management of the effectiveness of quality control.

IV The arrangement of joint meetings, the interchange of individual members among the several societies, and the mutual use of speakers of national prominence.

V The promotion of the point of view that control technique is efficient in the broad field of quality.

VI The expansion of the program in directions which will be of interest to technicians and educators so that mutual benefit may be derived from interchange of ideas, points of view, methods, and results.

BE IT RESOLVED, that the name of the federation shall be the Society of Quality Control Engineers as now registered in Washington and that the management of this society shall be lodged in a Board of Directors composed of one representative duly elected or appointed to this board by the individual societies subscribing hereto and two or more outstanding authorities in the field of Quality Control.

BE IT FURTHER RESOLVED that the editorial board of the magazine, INDUSTRIAL QUALITY CONTROL, shall be composed of two members elected or appointed by the member societies, supplemented by advisors of note in the field.

AND BE IT FURTHER RESOLVED, while this initial co-operative effort is now undertaken by the subscribing societies, that the combining groups will welcome participation in this federation by any similar group that seriously embraces and practices the tenets of quality control.

statistical methods in controlling quality of chemical processes. He pointed out, much to the satisfaction of our members who are connected with the chemical industry, that statistical methods of quality control are as applicable to chemical problems as they are to straight line production problems.

Mr. Dunlap said that he looked on statistics in two ways: One as a mathematical analysis of numbers that enables us to condense and summarize data, to indicate when assignable causes of variation are probably present, to determine whether or not two sets of results are significantly different, to determine the correlation between two sets of corresponding data and the like. It is comparatively easy to train workers to keep control charts or to calculate averages and standard deviations or correlation coefficients, but to get across the second phase is something else again. The second and by far the most important part of the statistical program is to develop statistical thinking. Members of an industrial organization such as managers, superintendents, technicians, research workers, foremen and salesmen should be mentally conditioned so that they really appreciate such things as the universality of variation, the meaning of control and the fact that lot quality is only estimated from sample quality.

One of the highlights of Mr. Dunlap's talk concerned the use of statistical methods to improve the recovery of a certain element. An analysis showed the following:

Heats	No. of Observations	Av. erage	Standard Deviation
Total	162	87.16	4.84
Standard Cond.	129	88.83	3.28
Subst'd'd Cond.	33	80.63	4.40

A control chart was made up on the second series of observations of heats which resulted in narrowing down the assignable causes to four items. The elimination of the third assignable cause resulted in boosting the average yield to 92%. The improvement was real and held up.

Mr. Dunlap outlined other applications of control charts to controlling various processes at Electro-Metallurgical and after this graciously answered the numerous questions which came from our membership.

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Advertising *possibilities*

INDUSTRIAL QUALITY CONTROL has over 700 paid subscribers and about 50 complimentary copies are sent to leaders in the field and in exchange for other magazines. At least 75 per cent of the subscribers are operators of Quality Control Systems in industrial plants scattered throughout the country. (Several months ago a tabulation showed that 31 states, Canada, England and Australia were represented.) These operators are quality managers, chief inspectors, methods engineers, design and tool engineers, research workers or persons employed in those branches of operation. They are the people who place orders for gages, micrometers, scales, comparators, hardness testers, tensile testers, tools, fixtures, jigs, dies, and machinery. These standard types of equipment are exclusive of all kinds of special recording and measuring devices which a manufacturer needs and has specially made for his operation.

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